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(54) Permanent-Magnet-Generator

DE 42 14 483 A 1

Die folgenden Angaben sind den vom Anmelder eingereichten Unterlagen entnommen

Beschreibung

Problem:

1. Generatoren allgemein brauchen Gleit- bzw. Wälzlager/Verschleißteil.

2. Permanentmagneterregte Generatoren haben die Eigenschaft, daß mit zunehmender Last (steigende Stromabnahme) im Spulenkern eine elektromagnetische Gegenkraft erzeugt wird, die dem Permanentmagnetfeld entgegenwirkt. Dadurch können im Spulenkern sehr hohe Temperaturen entstehen.

Dieses Problem wird in der Regel durch folgende Maßnahmen gelöst:
Zu 1 Rotoraufnahme durch Wälz-Gleit oder Magnetlager.
Zu 2 Wärmeabfuhr durch ein flüssiges Kühlmedium (Öl, Wasser o. ä.)

Nachteile: Flüssigkeitsgekühlte Generatoren sind vom Aufbau her aufwendig, kompliziert, schwer und nicht wartungsfrei.

Generatoren mit aktiver Luftkühlung können bei hohen Umgebungstemperaturen die zulässige Betriebstemperatur überschreiten. Durch die aktive Flüssigkeits- bzw. Luftkühlung wird der Gesamtwirkungsgrad des Generators beeinträchtigt.

Lösung des Problems Erfindung

a) Wärmeabfuhr

Beim Zweischeibenläufer-Permanentmagnetgenerator mit axialem Magnetfluß (siehe **Abb.** 1) drehen sich die beiden Magnetscheiben **1** und **2** über den Stator bestehend aus Eisenkern und Spulen (siehe **Abb.** 1 und 2). Die Magnete (**Abb.** 3) sind auf den Magnetscheiben so angebracht, daß zwischen den Magneten Luftkanäle entstehen. Durch die Drehbewegung der Magnetscheiben wird an der Außenkante der Magnetscheiben ein Unterdruck erzeugt, so daß durch die offene Nabe des Generators (**Abb.** 2) Kühlluft eintreten kann. Die Kühlluft tritt durch die Luftführungsschlitze der Nabe und verteilt sich gleichmäßig auf den Umfang des Stators, bestehend aus Eisenkern und Spulen (**Abb.** 2).

Ein weiterer neuer technischer Gegenstand ist der gesplittete Eisenkern (**Abb.** 2). Ein Teil der im Stator entstehenden Verlustwärme wird über einen Wärmeleitung (**Abb.** 2 und 4), an dem die beiden Eisenkerne thermisch gekoppelt sind, über den Wärmeleitsteg nach außen geführt. Der Wärmeleitring ist an Bolzen mit guter Wärmeleitfähigkeit aufgehängt, die gleichzeitig als Montagebolzen dienen (**Abb.** 2). Jeder Wärmeleitsteg (**Abb.** 4) ist an einen Montagebolzen thermisch und mechanisch gekoppelt, so daß eine optimale Wärmeabfuhr gewährleistet ist. Die aus dem Stator abgeleitete Verlustwärme wird durch den Luftstrom (**Abb.** 2) nach außen geführt. Durch die Art der Magnetanbringung und den besonderen Aufbau des Stators kann auf jede aktive Kühlung verzichtet werden.

b) Lagerung von Rotor und Stator

Die Lager für rotierende Komponenten sind in der Regel Verschleißteile und müssen in regelmäßigen Abständen ausgewechselt werden. Bei den neuen PM-Generator sind die Scheibenläufer so ausgelegt, daß sie direkt auf der Welle bzw. Scheibe des Antriebsaggregates montiert werden können. Der Generator hat keine Verschleißteile (siehe **Abb.** 2). Der Stator wird direkt am Gehäuse des Antriebsaggregates angeflanscht (siehe **Abb.** 2).

Patentansprüche

1. Permanent-Magnet-Generator oder Motor, insbesonders mit axialem Magnetfluß, mit stehendem Spulenkern und ein oder mehreren rotierenden Magnetscheiben, die Permanentmagnete enthalten, **dadurch gekennzeichnet,** daß die Nabe Öffnungen für den Eintritt der Kühlluft hat, daß zwischen den Magneten Kanäle zur Führung der Kühlluft radial nach außen vorgesehen sind, daß die Eisenkerne der Spulen gesplittet sind und daß eine oder mehrere Wärmeleitplatten vorgesehen sind, die in die Spalten der Eisenkerne eingreifen und die Wärme radial nach außen leiten.

2. Permanent-Magnet-Generator oder Motor, insbesonders mit axialem Magnetfluß, mit stehendem Spulenkern und ein oder mehreren rotierenden Magnetscheiben, die Permanentmagnete enthalten, dadurch gekennzeichnet, daß der stehende Spulenkern am Gehäuse des Antriebsaggregats (beim Motor am Gehäuse des Drehmoment aufnehmenden Aggregats) angeflanscht ist und der/die rotierende(n) Magnetscheibe(n) direkt (ohne eigene Lager) auf der Welle des Aggregats befestigt ist.

Hierzu 4 Seite(n) Zeichnungen

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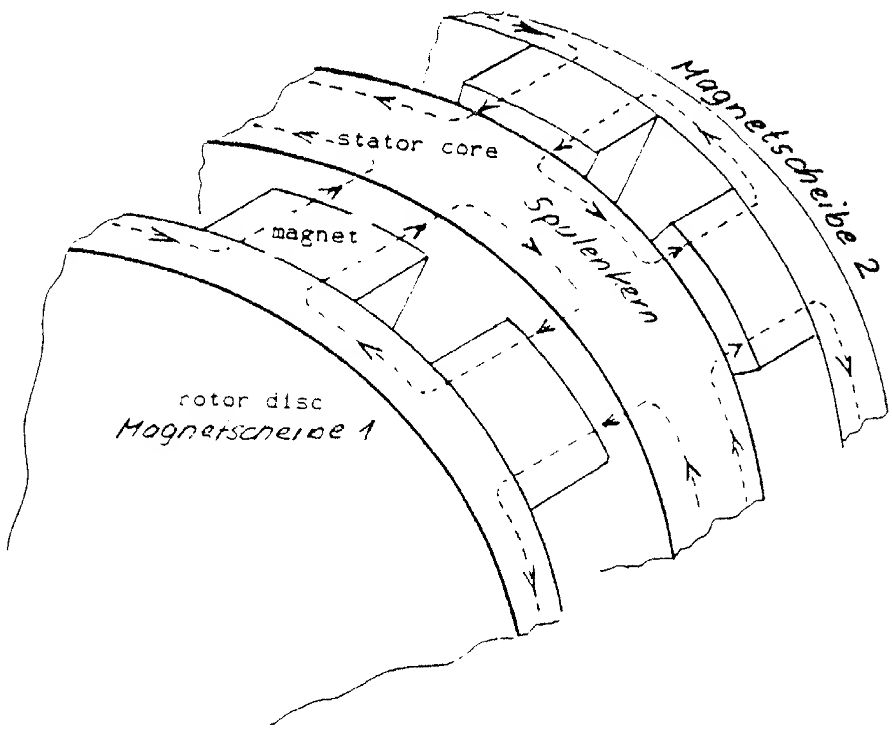
Int. Cl.5: H 02 K 21/00
Offenlegungstag: 11. November 1993



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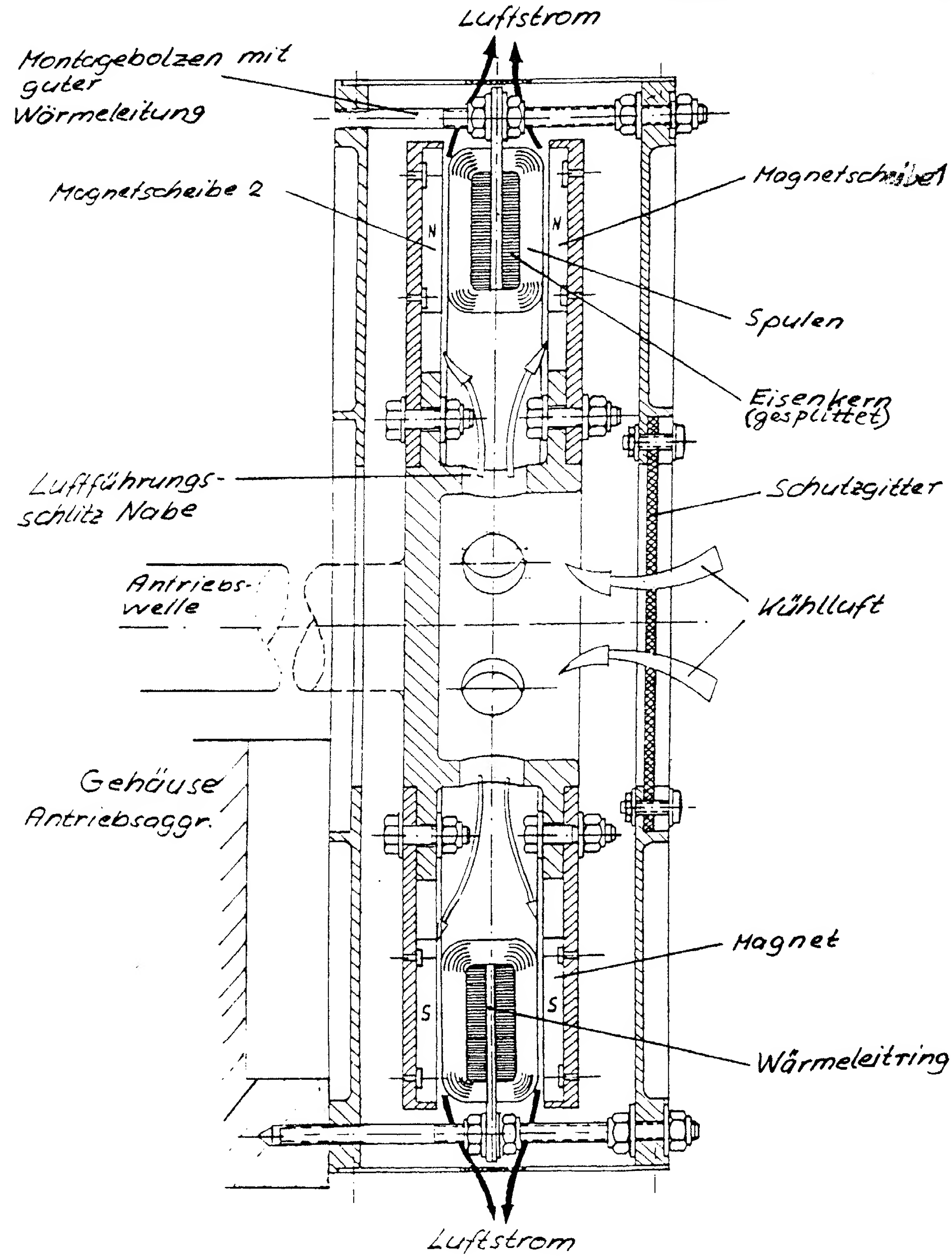

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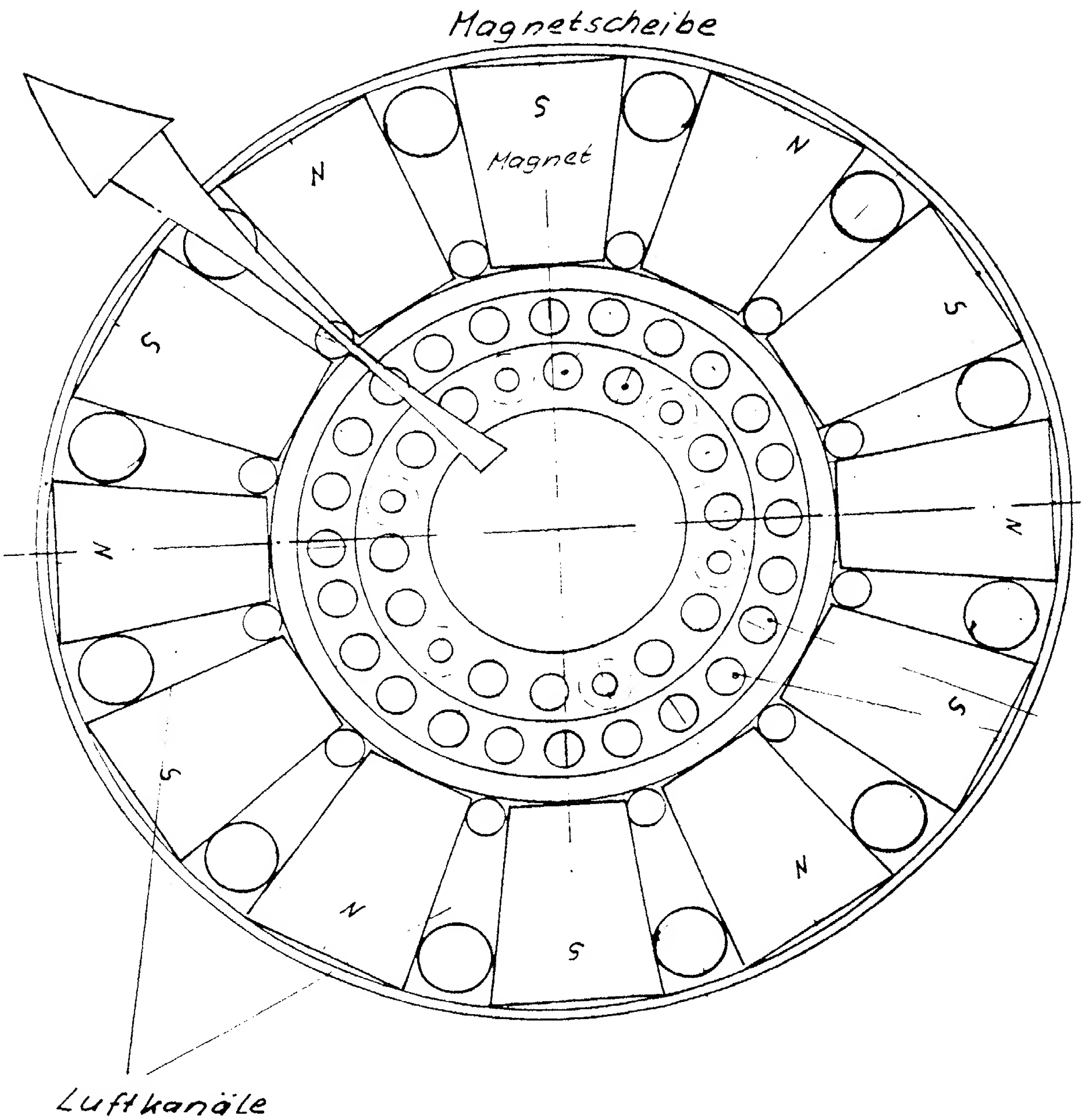

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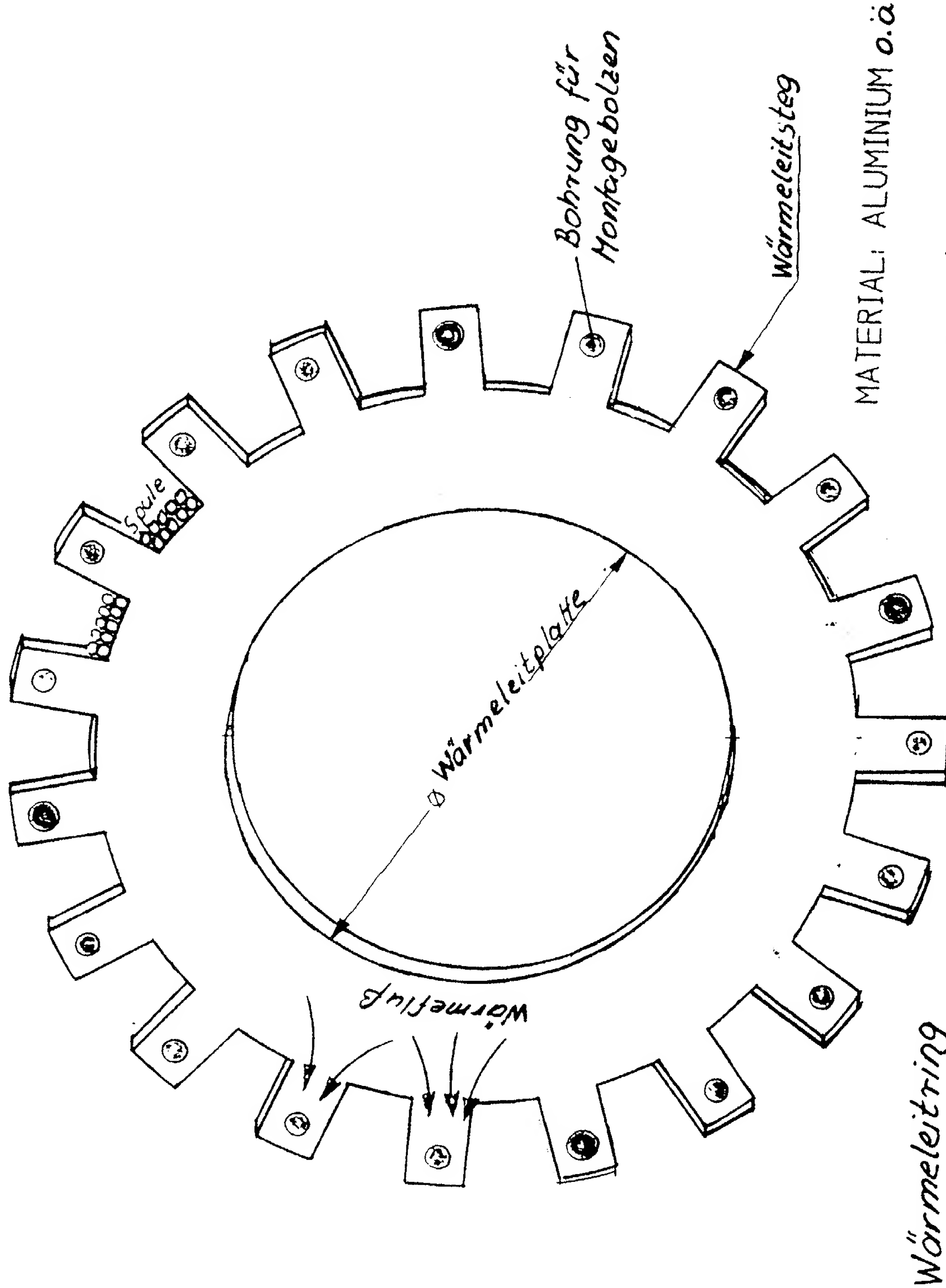

Abb.: 4

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(58) Field of Search
UK CL (Edition M) H2A AKR1 AKT3 AKT4
INT CL^5 H02K 1/27 21/24 29/08 29/10 29/12 29/14

(54) **An electronically commutated electric motor**

(57) A rotor 12, having a plurality of magnetic devices eg permanent magnets 21 around its axis, is located between stator elements 14 carrying coils 15, the motor including a Hall sensor to sense the position of the rotor and control the current supply. An inverting circuit is disclosed. The relative dimensions of the rotor/coil diameters and the coil size/separation are disclosed. The coils on the stator may be circumferentially offset from the other set of stator coils. The stator body may be formed with ventilation inlet ports near the rotor shaft and with ventilation outlet ports near the periphery of the rotor, the air flow being driven by the centrifugal action of the rotor. The relationship between the rectified wave form, applied current and the pulse-wave form are disclosed as is the relationship between the magnet and coil dimensions to interactive torque.

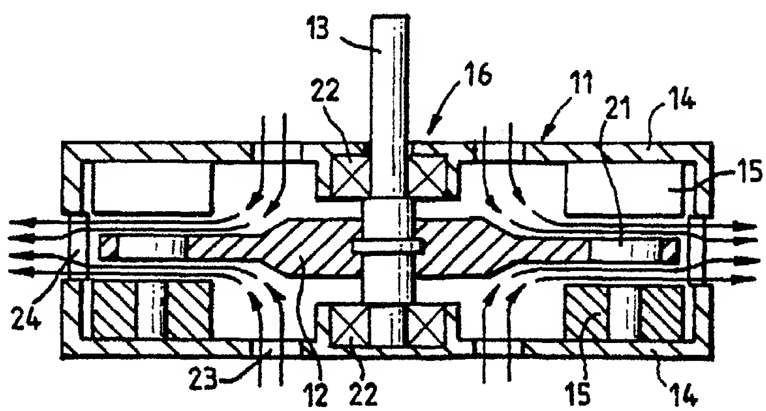

FIG.6

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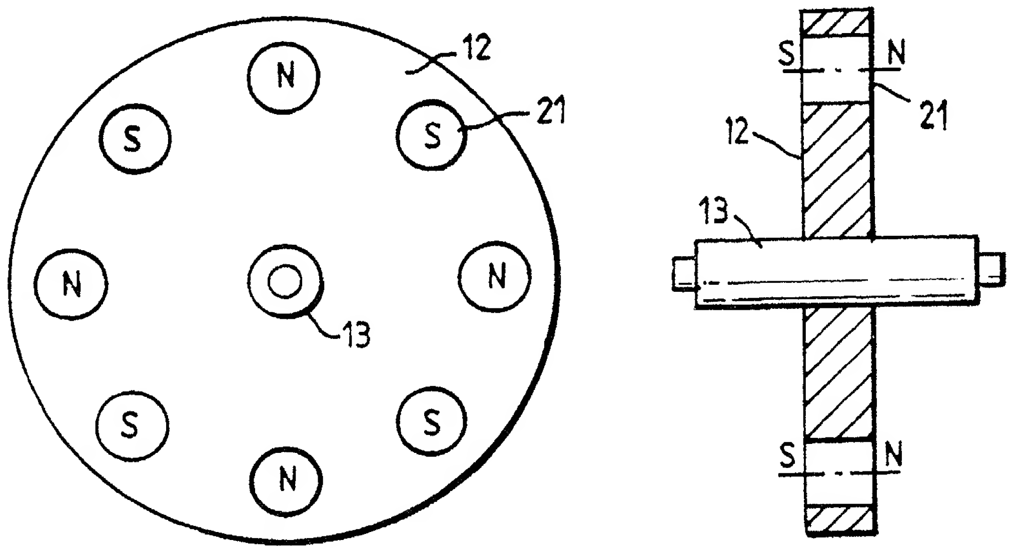
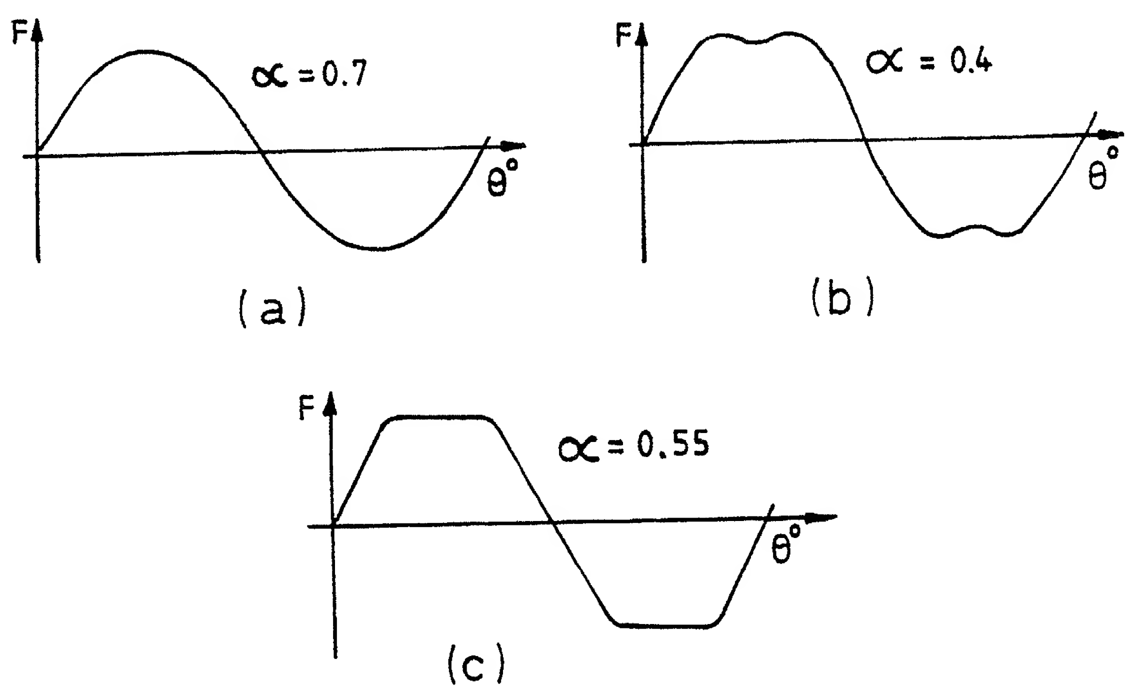
At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

The claims were filed later than the filing date within the period prescribed by Rule 25(1) of the Patents Rules 1990.



12
21
N
S
N
N
S
S
N
S
13
S
N
21
12
13
S
N

FIG.1



F
$\alpha = 0.7$
$\theta°$
(a)
F
$\alpha = 0.4$
$\theta°$
(b)
F
$\alpha = 0.55$
$\theta°$
(c)

FIG. 2

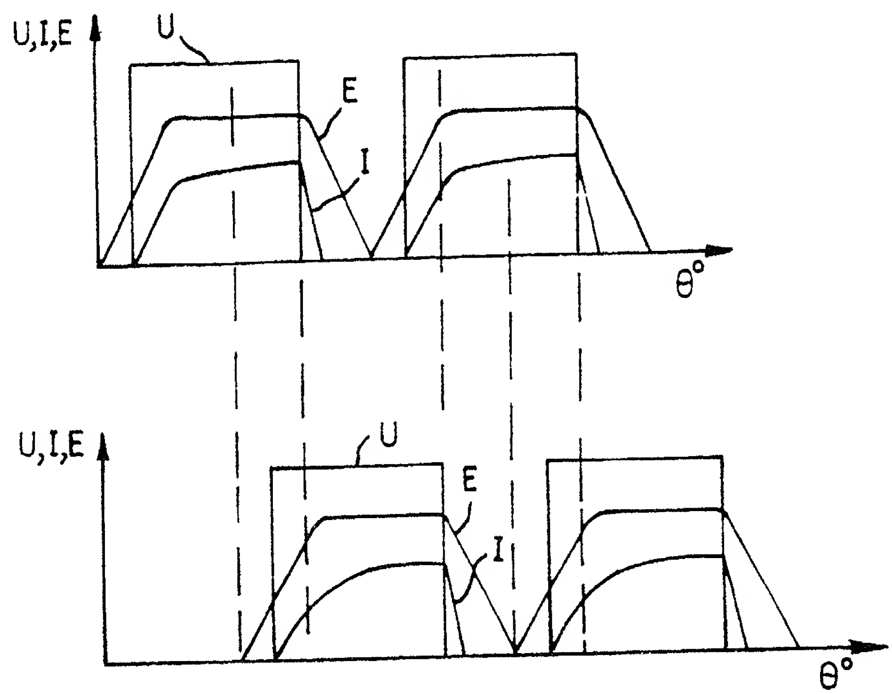


FIG. 3

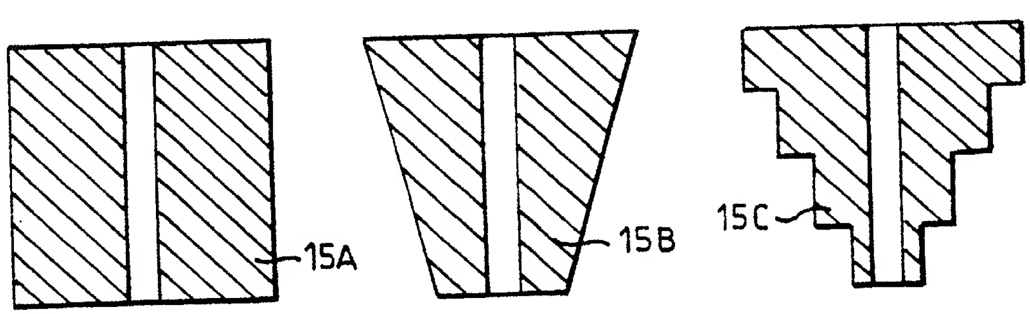


FIG.4

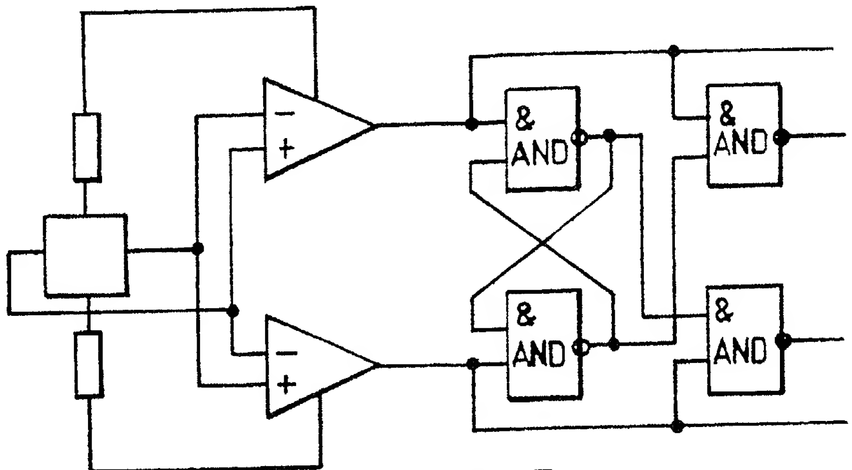


FIG. 5

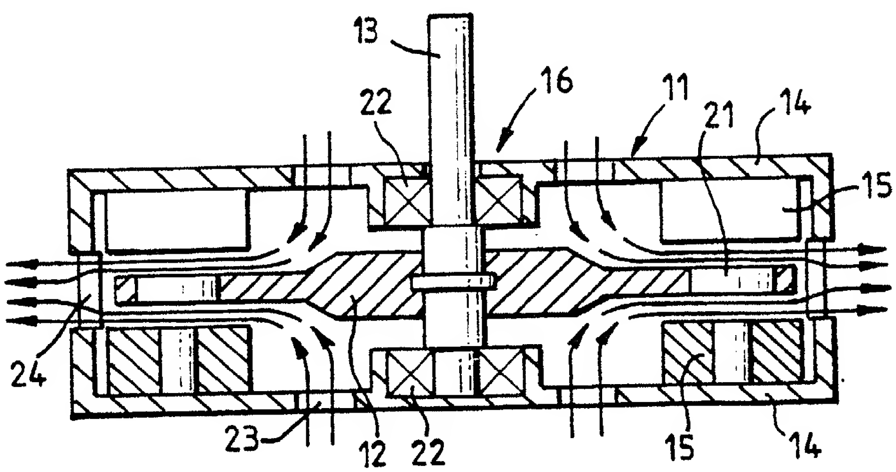


FIG.6

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ELECTRIC MOTOR

In an induction motor, the stator provides in operation a rotating magnetic field which reacts with a rotor and causes the rotor to rotate. Power is taken from the rotor shaft. In the squirrel cage induction motor, the rotor comprises a plurality of conductors arranged as generators of a cylinder around the rotor shaft, joined together at their ends, the current flowing through the conductors reacting with the rotating magnetic field created by the stator to cause the rotor to rotate.

In its first aspect, the present invention does not use a rotor which contains electrically conductive material and instead comprises a rotor having a plurality of magnetic devices arranged around its axis, means to generate magnetic fields in a stator which fields rotate around the axis to react with the devices of the rotor and urge it to rotate and a sensor to sense the position of the rotor and control said means accordingly. The magnetic devices are preferably permanent magnets.

The motors of this type have a number of advantages over the commutator and induction motors. As they have no brushes they can be left 'unserviced' for long periods; they also have a high specific energy capacity and can easily be controlled.

DE-C-2533187 discloses an electric motor having a rotor containing an even number of permanent magnets arranged around the axis with their poles aligned with the axis and a stator having an equal number of coils which can be energised to produce a rotating field. In this arrangement, the coils of the stator are arranged on one

side only of the rotor. The present invention in its first aspect improves upon this arrangement by providing coils on either side of the magnets of the rotor. The earlier specification provides a disc of soft magnetic material mounted on the rotor and located on the opposite side of the coils from the permanent magnets and the present invention does not require such a soft magnetic disc. With the arrangement of the present invention, there is greater efficiency.

The electric motor is preferably responsive to a direct energising current, the direct current being converted by a suitable inverter circuit to an alternating current whose frequency can be adjusted in order to create a field rotating at a suitable speed in the stator.

The ratio of the diameter of the magnet to the diameter of the coil is preferably in the range 0.5 to 0.6. The ratio of the diameter of the coil to the distance between the centres of the coils is preferably in the range 0.9 to 0.95. The coils of the stator are preferably of smaller diameter at the end remote from the rotor than at the other; they may be stepped or in the shape of a truncated cone. The coils on one side of the rotor are preferably fixed in a position spaced by a fraction less than half (eg 0.25 - 0.35) of a pole division in advance of the coils on the other side of the rotor. This low fraction has been found to operate better than the fraction of one half which has previously been used, and gives a more uniform drive to the rotor while decreasing noise level and increasing efficiency. The diameter ratios can be applied to electric motors which do not have coils on both sides of the rotor.

In another aspect of the invention there is provided an electric motor comprising a stator body, a disc-shaped rotor rotatable on a shaft mounted in the stator body, the stator body being formed with ventilation inlet ports near the rotor shaft and with ventilation outlet ports near the periphery of the rotor.

An example of the invention will now be described with reference to the accompanying drawings in which:

Figure 1a is a plan and Figure 1b a section of a rotor,

Figure 2 shows waveforms of torque against relative positions of magnets and coils for different ratios of the magnet radius to the coil radius,

Figure 3 shows the times of energisation of coils in relation to relative magnet position,

Figure 4 shows different coil sections,

Figure 5 shows a circuit for a Hall effect position sensor, and

Figure 6 is a section through the motor showing air ventilation flows.

The motor illustrated in the drawings is of squat cylindrical shape and comprises a stator 11, a rotor 12 having an output shaft 13 on the axis of the cylinder, a position sensor and a transistor commutator (the latter two not shown). The housing of the stator 11 comprises two separable half-cylinders 14, each half

housing a set of eight electromagnetic coils 15 equally spaced on a circle around a journal 16 encircling the axis of the motor. The two halves 14 of the housing are secured together by bolts passing through apertures in one half to threaded holes in the other half, locating devices being provided to ensure that the two halves are correctly oriented when fixed together. The coils 15 of one set are displaced around the circle relative to the coils of the other set as discussed below with reference to Figure 3. The coils of the stator are of cylindrical form and are connected in series, which makes it possible to wind all the coils of one half of the stator at one go and, after covering them with a potting substance, put them on the pins of the stator casing. Apertures are cut in the side wall of the housing to provide access to the coils and ventilation.

Although the stator coils may be cylindrical (15A), they may have a radius which varies from a maximum at the end facing the other half of the stator to a minimum at the remote end. This leads to maximum efficiency since the induction of a cylindrical magnet decreases more slowly along its axis than at its periphery. The variation from maximum to minimum may be uniform so that the coil is of trapezoidal axial cross-section (15B) or it may be stepped (15C), as shown in Figure 4.

The rotor 12 comprises a disc of non-magnetic material carrying eight permanent cylindrical magnets 21 whose poles are arranged parallel to the axis of the disc and alternately poled, that is, one magnet has its north pole on the same side of the disc as the south poles of the adjacent magnets. The magnets are arranged around a circle on the disc equal in radius to those of the

stator coil axes. The disc is of a polymer material in which the magnets are cast. The rotor shaft is provided with ball bearing journals 22 which fit into the journal housings 16 in the two halves of the stator to enable the rotor to rotate at high speed without undue friction.

DC power is supplied to the casing of the motor through an inverter circuit driving a commutator controlled by the position sensor responding to the position of the rotor to create a field which rotates around the axes of the coils and magnets, thus urging the rotor to follow the field generated by the coils. These items are not illustrated.

The relationship of the radius of the rotor magnet 21 to the radius of the stator coil 15 affects the interactive torque between these components as their relative position changes. Waveforms are shown in Figure 2 to illustrate the relationship of energy to relative position for different radius ratios, waveforms A, B and C being for ratios 0.7, 0.4 and 0.55, respectively. Whereas the waveform for a ratio of 0.7 is approximately sinusoidal, that for a ratio of 0.4 has a double peak for each half cycle of the approximate sine wave. The compromise ratio of 0.55 and ratios in the range of 0.5 to 0.6 provide an approximate trapezoidal waveform with a broad flat peak to the half cycles of the curve. Using a ratio in this range, the interactive energy is thus uniform for a wide range of angular separations of the magnet and coil.

In order to provide a field which exerts maximum force on the adjacent rotor magnet it is arranged that a

stator coil is only energised when the nearby rotor magnet is in the range of relative positions corresponding to the extent of the plateau and for a short period immediately preceding the plateau, the coil being otherwise unenergised. This is shown in Figure 3. In Figure 3, the waveform E corresponds to the rectified waveform of Figure 2 appropriate to $\lambda = 0.55$. Waveform I is the corresponding current and waveform U is the waveform of the pulses applied to the coils. It will be seen that the pulses start as the current waveform rises from zero and ends when it reaches its peak, which is also when the waveform E completes its plateau and starts to fall. The rapid switching is made possible by the transistor commutator provided.

With four pairs of coils on each side of the rotor, the rotor takes 1/4 revolution to pass the coils. Within this quieter revolution, one complete cycle of the waveform shown in Figure 2c takes place. The corresponding square wave pulses of Figure 3 also occupy one quarter of a revolution: within this period there is the first pulse, to be applied to the first coil of the pair, and the second, inverted, pulse, to be applied to the second coil which is oppositely poled, so that the torque applied to the rotor by each pulse is in the same direction. No torque is applied by the pair of coils except during the two pulses U. These periods of no torque are however compensated for by displacing the pair of coils on the half of the stator on the other side of the rotor so that the square pulses of the latter pair of coils occur between the pulses of the first pair. Since the full period of the waveforms corresponds to 1/4 revolution $\approx 90°$, a displacement between the two pairs of coils of 22.5° will line up the

pulses of one pair with the gaps between pulses of the other pair. In general, for a system with n pairs of coils on each side of the stator, the relative displacement should be $(360/4n)° = 90°/n$. Ideally for uniform torque the mark/space ratio of the pulses U of Figure 3 should be 1 : if it is greater, torque will still be applied all the time, but for some periods torque will be applied from coils on both sides of the rotor; if it is less there will still be periods of no torque.

The position sensor comprises a special network including a Hall effect device. Usually no fewer than two Hall detectors are used in a two-phase motor, which makes the position sensor more expensive. A special circuit has therefore been devised which allows the four impulses shifted by 90° divided by n (where n is the number of pairs of poles, 4 in this case) to be derived from one Hall detector, the circuit being illustrated in Figure 5.

It has been found that such a motor will provide power comparable with conventional electric motors of very much greater size and weight.

As shown in Figure 6, ventilation is provided by the draught caused by the rotation of the rotor 12. Air is entrained by the rotating disc, being drawn in from ports 23 in the stator body near the rotor shaft and expelled from ports 24 in the stator body around the periphery of the rotor by the centrifugal action of the rotor rotation. This ventilation system can be applied to any electric motor with a disc-shaped rotor.

CLAIMS

1. An induction motor comprising a stator, a rotor having a plurality of magnetic devices arranged around its axis, means to generate magnetic fields in the stator which fields rotate around the axis to react with the devices of the rotor and urge it to rotate and a sensor to sense the position of the rotor and control said means accordingly.

2. A motor as claimed in claim 1 wherein said magnetic devices are permanent magnets.

3. A motor as claimed in claim 1 or claim 2 comprising an inverter circuit for converting a direct energising current to an alternating energising current for said generating means, and means to adjust the frequency of the alternating current.

4. A motor as claimed in any one of claims 1 to 3 wherein the magnetic devices have a first diameter and the stator comprises a number of coils, corresponding to the number of magnetic devices, of a second diameter, the ratio of the first diameter to the second diameter being in the range of 0.5 to 0.6.

5. A motor as claimed in any one of the preceding claims wherein the stator comprises a number of coils, corresponding to the number of magnetic devices, of a given diameter, the ratio of the given diameter to the distance between the centres of the coils being in the range 0.90 to 0.95.

6. A motor as claimed in any one of the preceding claims wherein the stator comprises a number of coils, corresponding to the number of magnetic devices, of smaller diameter at the end remote from the rotor than at the other end.

7. A motor as claimed in claim 6 wherein the diameter of the coils changes in steps between its ends.

8. A motor as claimed in any one of the preceding claims wherein the stator comprises a number of coils corresponding to the number of magnetic devices arranged on both sides of the rotor, the coils on one side of the rotor being arranged in advance of the coils on the other side of the rotor by a given distance less than the distance between adjacent coils on one side of the rotor.

9. A motor as claimed in claim 8 wherein said given distance is in the range 0.25 to 0.35 of said distance between adjacent coils.

10. An electric motor comprising a stator body, a disc-shaped rotor rotatable on a shaft mounted in the stator body, the stator body being formed with ventilation inlet ports near the rotor shaft and with ventilation outlet ports near the periphery of the rotor.

11. An induction motor substantially as hereinbefore described with reference to the accompanying drawings.

Patents Act 1977 **Examiner's report to the Co...ptroller under Section 17** **(The Search report)** 10	Application number GB 9302761.3
Relevant Technical Fields (i) UK Cl (Ed.M) H2A (AKR1, AKT4, AKT3) (ii) Int Cl (Ed.5) H02K 29/08, 29/10, 29/12, 29/14, 21/24, 01/27	Search Examiner J COCKITT Date of completion of Search 15 MARCH 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1-3

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Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 2107536 A	(EMERSON) see for example Figure 1	3 at least
X	GB 2083302 A	(STARKSTROM) see for example Figure 3	3 at least
X	EP 0319632 A1	(PORTESCAP) see Figure 2	1-3 at least
X	EP 0123347 A1	(MAVILOR) see whole document, especially Figures 1, 16, 17	1-3 at least
X	WO 84/01062 A1	(RABE) see Figures 10, 11	1-3 at least
X	US 4459502 A	(WESTINGHOUSE) see whole document	3 at least

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